

## ***Does reintroduction stabilize the population of the critically endangered gharial (*Gavialis gangeticus*, Gavialidae) in Chitwan National Park, Nepal?***

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### ABSTRACT

1. Despite conservation programmes (India 1975, Nepal 1978) gharial populations (*Gavialis gangeticus*) have declined over their entire distribution range. Information about the current status and main threats is needed to implement effective conservation measures.

2. This study presents a survey (2003/2004) of the largest Nepalese gharial population in the Chitwan National Park that has benefited from regular re-introduction of young gharials since 1981.

3. Population size estimates fluctuate between 34 (2003) and 38 (2004). The reintroduction programme, although of limited success, has helped to maintain the gharial population.

4. Gharials bask preferentially in large sand banks, and these sites must be protected.

5. The main threats are from a dam that causes fish depletion and flushes gharials from the protected area, sand mining and grazing that destroy basking sites, fishing that causes food shortage, drift nets that kill gharial, and water pollution.

6. Improvement in the survival of reintroduced gharials is needed. Strict protection of preferred basking sites and prohibition of fishing in the main settling zones are the principal conservation measures while in the long term, education and participatory management by local people are also necessary.  
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### INTRODUCTION

The gharial (*Gavialis gangeticus* Gmelin, 1789), listed in 1975 in Appendix 1 by CITES (CITES, 2006), is now listed as Critically Endangered on the IUCN Red List (IUCN, 2007). Wild populations fluctuated in the last decade and unfortunately exhibited a worrying decline. This species was formerly found throughout the Indian subcontinent, including rivers of Pakistan, Burma, Bangladesh, North India, Nepal and Bhutan (Whitaker and Basu, 1982). With only 250 to 300 individuals in the entire Ganges basin, the gharial was close to extinction in the 1970s due to human pressure (Grenard, 1991). The creation of protected wetland areas, in conjunction with a reintroduction programme of captive-reared individuals undertaken in India and Nepal, restored the population to

approximately 1500 individuals (Andrews and MacEachern, 1994; Hussain, 1999; Whitaker and Andrews, 2003). Despite conservation efforts, gharial populations remain fragile. For instance, in the largest gharial population in the world (National Chambal Sanctuary) numbers decreased by 40% between 1998 and 2007 (Hussain, 2009). In 2006, adult population size was estimated to be 200 individuals in India and 35 in Nepal. In the other countries, gharials are considered virtually extinct (Whitaker and Members of the GMTF, 2007).

The Gharial Conservation Project in Chitwan National Park (CNP, Nepal) was launched in 1978. Because neonate annual survival rate is very low under natural conditions (7.7%; Hussain, 1999), and because only 5.5% of hatchlings are recruited in the population (Hussain, 1999), a reinforcement programme was set up. Eggs were collected in the field, artificially incubated, and the

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neonates raised for 4 to 7 years before releasing (Maskey, 1989). From 1981 to 2007, 691 young specimens reared in captivity have been reintroduced, including 438 in the two main rivers of the CNP: the Narayani River, and the Rapti River (Forestry Nepal, 2008). In 1993, a survey performed in Nepal reported 58 wild gharials and 75 reintroduced (Maskey and Percival, 1994). In the rivers of the CNP 32 wild gharials and 20 introduced gharials were recorded, most of them on the Narayani River. The survival of the captive-reared gharials in the Narayani was estimated at 7% (Maskey and Percival, 1994). Although the project is the only management programme established to sustain the gharial distribution in Nepal's rivers, its efficiency has been questioned (Maskey, 1989; Maskey and Percival, 1994).

Therefore, further conservation efforts are critical. The French–Nepalese collaboration initiated in 2001 at the Crocodile Farm of Pierrelatte (France) aimed to examine the state of the gharial population 10 years after the last census in 1993, and determine the efficiency of the reintroduction programme. Between 2002 and 2006, 56 released gharials were monitored (Cadi *et al.*, 2002, 2005, 2008). For this study wild and released animals in the rivers of the CNP were counted in 2003 and 2004. This study presents results of the population distribution and ecological characteristics of preferred basking

sites of the gharial in order to identify possible threats. The final objective of this study was to propose effective conservation measures to protect one of the most significant remaining gharial populations.

## METHODS

### Study site

The Narayani and Rapti rivers delimit respectively the north and west boundaries of the CNP (83°50' to 85°00' E, 27°15' to 27°40' N). Both rivers are influenced by the subtropical climate of the Terai region with two distinct periods, the monsoon (May to November, 80% of the annual precipitation) and dry season (December to April). The Narayani is a powerful river (1000–1700 m<sup>3</sup> s<sup>-1</sup> in low water periods) that flows from the Himalayan hills. A dam at the Nepal/India border is used for irrigation and flood control. The Rapti River is smaller and confined to the Terai plain. It relies on local rains and as a consequence is warmer than the Narayani (Maskey, 1989).

Five river segments (15–30 km each) along a total of 112 linear kilometres of river were studied (Figure 1; Table 1).

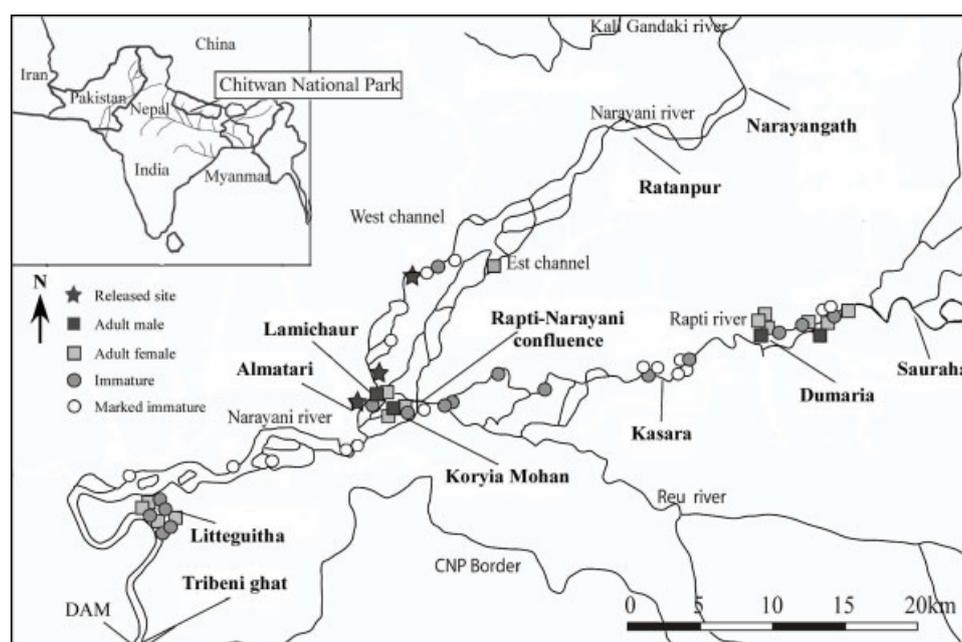


Figure 1. Study area and distribution of gharials in Chitwan National Park during the survey in 2004. The location of individuals does not illustrate their movement (see Table 1). Symbols show where individuals have been mostly sighted.

Table 1. Locality of the release site, number of reintroduced gharial in 2002/2003 and their observation in 2004 among the different segments of the rivers of Chitwan National Park

River	Rapti		Narayani			Total
	Sauraha-Kasara (S-K)	Kasara-Rapti-Narayani Confluence (K-A)	Ratanpur-Amaltari West Channel (R-AW)	Ratanpur-Amaltari East Channel (R-AE)	Amaltari-Tribeni (A-T)	
Gharial reintroduced (2002–2003)			20–6		0–10	36
Observations	1	0	0	1	0	2
	0	1	0	0	0	1
	4	2	3	0	4	13
					Total	16

The last survey performed in 1993 indicated that most of the gharials were found in the Narayani River and its main affluent, the Kali Gandaki situated north of the park (more than 30 wild adult gharials in the Narayani and nine wild individuals in the Kali Gandaki). At that time no wild gharials were found in the Rapti River, although several individuals have been released there since 1981 (Maskey and Percival, 1994).

### The reintroduction programme

Since 1981 gharial populations of the CNP have been dependent on annual reintroduction of young crocodiles. A major cause of the population decline in Nepal has been the flooding of nests caused by the damming of rivers, which provokes abnormally high floods during heavy monsoon seasons (Maskey, 1989).

To allow hatchling survival and promote juvenile survival, eggs were removed from their natural environment and artificially incubated at the Gharial Monitoring Centre (CNP, Kasara). Mean clutch size of nests varied between 34.4 and 37.0 eggs (Maskey, 1989). The neonates were raised in captivity for 4–7 years until they attained on average a body size of 1.5 m (under this size, gharials have a low survival rate) before release (Maskey and Percival, 1994). Since 1981, each year immature crocodiles were reintroduced into the rivers. In this study, from March 2002 until November 2003, 36 gharials were released at three different times (Table 1). Released individuals were marked with cattle tags attached to a tail scale. Cattle tags remained attached at least 2 years after fixation, but it was possible to read the numbers for one year only. In addition, notches in the caudal scales enabled individuals to be marked permanently (Figure 2).

### Population surveys

Surveys were undertaken during two different periods from November 2002 to April 2003, and from November 2003 to May 2004. For each survey, the Narayani and Rapti rivers were divided into five segments. Each segment was surveyed during the first (six occasions) and the second period (seven occasions) for a total of 13 occasions. Two people on two kayaks surveyed each segment every two or three weeks. Binoculars were used to carefully observe the areas likely to host animals. The surveys were performed at the most appropriate time of day: from 10 a.m. to 4 p.m. when the temperatures were cold (November to February air temperature ranged between 5 and 25°C), considered as the better period for census, and from 8 a.m. to 2

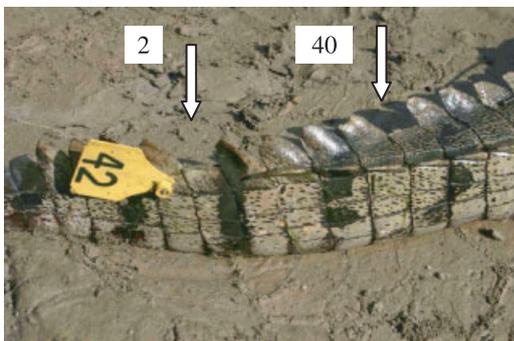


Figure 2. Mark on scales with cattle tags and notches on individual number 42 (see notches at the second vertical scale (number 2) and the fourth left horizontal scale (number 40)).

p.m. once temperatures increased (March to May air temperature ranged between 18 and 44°C) (Whitaker and Basu, 1982; Rao *et al.*, 1995).

To characterize age/sex classes the following criteria were used:

1. Gharials less than 2.8 m in total length (TL) were considered immature. Maturity is generally attained at a body size over 3 m, and an age of 13–14 years. This criterion is not absolute, and, for instance, an 18-year-old male measured only 2.7 m (Singh, 1979; Hussain, 1999). This category includes gharial less than 2.20 m, probably from previous releases (2000–2002), and individuals above 2.20 m, probably from releases before 2000.
2. Individuals above 2.8 m with a growth (ghara) at the tip of the snout (Biswas *et al.*, 1977) were considered to be adult males. This category also includes individuals above 2.20 m.
3. Individuals above 2.8 m without ghara were considered to be adult females (Biswas *et al.*, 1977).

These two last categories also included individuals above 2.20 m.

Population estimates included marked individuals released before 2002 (without permanent marking). The minimum size of the population was estimated by direct count. This number was composed of those counted during the most favourable period (February) when gharials seen were the highest, plus additional individuals known to be present but missed during the best counting period.

The survey of reintroduced animals was performed in 2004 during the census of the wild population. The location of each observed gharial was recorded using a GPS with a precision of 50 m because readings were recorded from a boat and from distance so as not to disturb the gharials.

### Ecological characteristics of basking sites

For most crocodiles, the selection of appropriate basking sites on river banks is crucial for thermoregulation and to escape predation. For each basking site where gharials were observed, water depth classes (D1: <1 m; D2: 1–2 m; D3: >2 m) of the adjacent river bed were measured. Basking habitat was classified into five categories: mixed bank, rock bank, sand bank, steep bank and sandy island (Maskey *et al.*, 1995).

Mixed: composed of sand and rock and/or grasses (e.g. *Polygonum plebujum*).

Rock: consisted mainly of stones or pebbles ranging in diameter from 50 mm to 250 mm.

Sand: high bank of fine sand without or with little vegetation and less than 30° slope.

Steep: more than a 30° slope consisting of sand alone or with vegetation.

Sandy island: fine sand crossed by waterways.

## RESULTS

### Status of the wild population

#### Census

A total of 245 observations of wild gharials were made during the two survey periods in the CNP (116 in 2002–2003 and 129 in 2003–2004). In 2002/2003 38 gharials were counted (three adult males, 12 adult females, 23 immatures (including seven

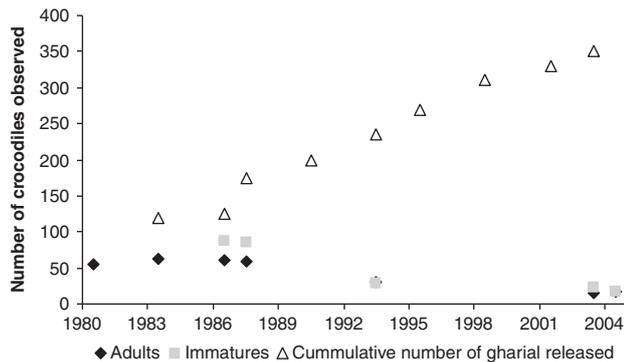


Figure 3. Crocodile population changes CNP (according to Maskey, 1989; Maskey and Percival, 1994; this study 2003/2004).

individuals <2.20 m) and 34 were counted in 2003/2004 (four adult males, 13 adult females, 17 immatures (including three individuals <2.20 m)).

Figure 3 shows that the population of gharials (adult and immature) observed in the wild is low although gharials have been regularly reintroduced since 1983 as well as a depletion of this population between 1986 and 2004. In 1993, the sex ratio was 1/10 (Maskey and Percival, 1994), but it is now of 1/4.

#### Distribution and density

Adults and immatures were homogeneously distributed in the Rapti and Narayani rivers. In both study periods, the highest concentrations of wild gharials occurred in the Sauraha-Kasara segment in the Rapti River (0.73 ind km<sup>-1</sup> in 2003–2004) and in the Amaltari-Tribeni segment in the Narayani River (0.39 ind km<sup>-1</sup> in 2003–2004). On the west channel of the Narayani River, the gharial density decreased from 0.33 ind km<sup>-1</sup> in 2003 to 0.16 ind km<sup>-1</sup> in 2004. Similarly in the east channel, the gharial density decreased from 0.33 ind km<sup>-1</sup> in 2003 to 0.14 ind km<sup>-1</sup> in 2004. Although gharials are scattered in these segments, their distribution is characterized by groups of animals at specific sites, particularly adults (Figure 1).

#### Status of the reintroduced gharials

##### Survival

From two successive batches of marked reintroduced gharials, 10 in March 2002 and 26 in March–April 2003, 16 individuals were observed in 2004. Five individuals (50%) from the March 2002 batch were seen in 2003, but only two in 2004 (20%). From the March–April 2003 batch, 14 were observed in 2004 (54%). Overall, 50% of the reintroduced gharials disappeared each year, suggesting a low success rate of reintroduction, at least in the first year after release.

##### Distribution

The 16 reintroduced gharials were observed on 59 occasions in 2004 (3.7 observations per individual). The distribution of the gharial was homogeneous within the various segments of the park (Figure 1). The three release sites were associated with three distribution patterns of the reintroduced crocodiles: 1. scattering as far as 20–40 km from the release site in the Rapti River in the Sauraha-Kasara segment; 2. settling near the release site; and 3. settling up to 20 km downstream from the release site in the Narayani River.

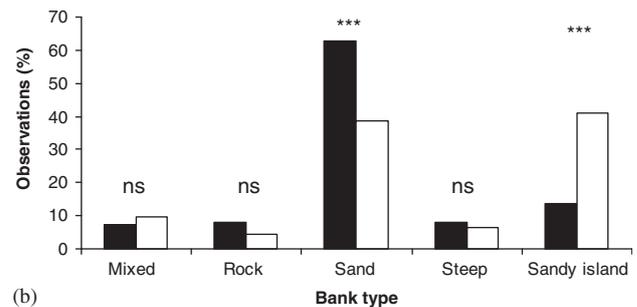
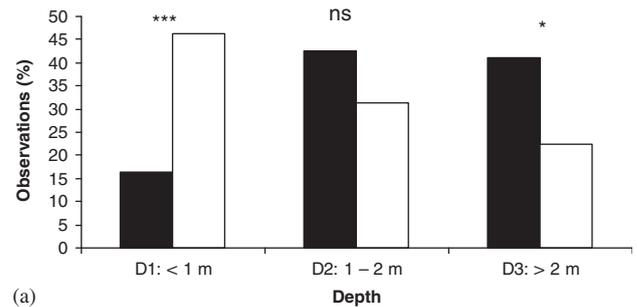


Figure 4. (a) Depth of water near basking sites of gharials (black bars: individuals >2.20 m, white bars: individuals <2.20 m, \*\*\* =  $P < 0.001$ ; \*\* =  $P < 0.01$ ; \* =  $P < 0.05$  see text for details) and (b) Distribution of the basking site of gharials (black bars: individuals >2.20 m, white bars: individuals <2.20 m, \*\*\* =  $P < 0.001$ ; \*\* =  $P < 0.01$ ; \* =  $P < 0.05$  see text for details).

#### Characteristics of basking sites

During the two survey periods, water depths were recorded in the vicinity of 211 basking sites and the habitat was described on 295 occasions. Larger gharials (adults and immatures; TL > 2.20 m) tended to be observed basking close to waters deeper than 1 m ( $\chi^2 = 17.32$ ; df = 2;  $P < 0.01$ ) while smaller individuals (immatures including released individuals; TL < 2.20 m) were mostly observed close to shallow water (< 1 m) ( $\chi^2 = 5.85$ ; df = 2;  $P > 0.05$ ; Figure 4(a)). Gharials preferred sandy banks to all other habitat types. Larger individuals were observed mostly on sandy river banks, more often than smaller individuals ( $\chi^2 = 234.88$ ; df = 4;  $P < 0.01$ ). Smaller individuals also used sandy 'islands' situated within the river more often than larger individuals ( $\chi^2 = 61.46$ ; df = 4;  $P < 0.01$ ; Figure 4(b)).

## DISCUSSION

#### Population status

Data from the current study, and those from recent surveys (Forestry Nepal, 2008) suggest that the gharials of CNP represent the main population of Nepal, the third largest in the world; however, it is extremely vulnerable. Long-term studies are needed to propose effective conservation measures and to provide a scientific basis to improve political support. Although the total number of individuals within the CNP, approximately 50 (wild + released), appears to be stable, the low success rate of reintroduction is worrying. According to Maskey and Percival (1994) only 19 gharials survived from 273 individuals released between 1980 and 1993 in the Narayani River. The recruitment of adult gharials from the pool of released juveniles is very low

(Madhu, 1977; Maskey, 1989); during the first years after release, annual survival of reintroduced specimens is estimated to be only 50%. Overall, the reintroduction programme maintains the population but it remains very fragile.

### Threats

Despite legal protection, a number of threats compromise the survival of gharial in Chitwan National Park (Maskey *et al.*, 2006). In the past, poaching of gharials and eggs for medicine, believed mystical values and food were considered the main threats. By the late 1970s the drastic depletion in their abundance and distribution was attributed to the lack of strict habitat protection. This study suggests that additional factors are likely to be important. Field observations enabled the main categories of threats to be identified.

- (1) The presence of the Nepal/India dam. The dam, not fitted with a fish ladder, causes food depletion (Madhu, 1977). Also, the release of monsoon overflow waters washes gharials out of protected areas (Bustard and Singh, 1983). However, considering the relatively high number of young gharials finding refuge in the slow-flowing Rapti River but that subsequently disappeared, other threats should be examined.
- (2) Human activity, grazing and fishing (Ballouard *et al.*, 2004; Cadi *et al.*, 2005). Sand mining is directly implicated in the loss of basking sites, and grazing of stock near river banks also results in the destruction of limited suitable habitat (Whitaker and Members of the GMTF, 2007; Hussain, 1999). Fishing activity reduces the number of fish on which gharial feed, disturbs basking activity, and leads to mortality caused by drift nets. Drift nets are prohibited but gharials with pieces of fishing net wrapped and tangled around their snouts are regularly observed. Small (young) gharials are the most vulnerable (Hussain, 1999), which could explain the low survival of released gharials.
- (3) Water pollution. Despite the lack of precise data, evidence suggests that water pollution plays a role. Industrial activity upstream on the Narayani River, notably beer and paper factories, produces waste chemicals and dirty water that are released into the river system. Over 10 years a spectacular distribution shift of the adult gharial population from the Narayani to the Rapti River was observed. Moreover, in strong contrast to 15 years ago, in the upper Narayani downstream of Narayangath (west and east channel), nests have become extremely rare with only one found per year in Lamichaur (Maskey, pers. commun.). However, both these segments of the Narayani contain suitable habitats that do not suffer from strong human disturbance compared with the Rapti River. This distribution shift into slower waters away from the downstream flow of potential waste products may reflect a reaction to water pollution.

### Proposals for conservation

With only 200 breeding adults scattered in a few small areas in India and Nepal, the gharial is today close to extinction (Whitaker and Members of the GMTF, 2007; GCA, 2008). Gharials in the past have responded well to protective

management initiatives (Whitaker and Andrews, 2003), but most of the efforts involved *ex situ* breeding and reintroduction into the population. The results of this study show that this strategy had limited success. Undoubtedly with respect to the current status and the fragility of the gharial, *in situ* and *ex situ* conservation efforts must be improved. Five main conservation measures are urgent:

1. The strict protection of basking sites (Hussain, 2009). Such places are situated near deeper shores where the river forms large bends against the current (Ciliberti, 2003). Females select such sites for nesting (Rao, 1988; Maskey, 1989), and the males are likely to use these sites to access females. Sites such as Koriyamohan and Littegintha on the Narayani, or Dumaria on the Rapti should be strictly protected from human activity especially from sand mining and fishing.
2. Prohibition of fishing in the main settling zones, notably around reintroduction sites.
3. Analysis and control of industrial waste.
4. Fish ladders should be constructed and fitted to the dam under fishery biologists' supervision (Madhu, 1977).
5. Captive breeding. The maintenance of the stock of captive-raised gharials is important for two main reasons. First, because captivity offers an alternative to avoid the extinction of the species. Second, artificially incubated eggs collected in the field and those obtained from reproduction in captivity provide the individuals for the reintroduction programme. Strong vigilance of the pool of captive gharials is needed in case of epizooty (Le Foll, 1982). Gharial should be fed only live fish for at least one month prior to their release to acclimate them to wild conditions (Maskey, 1989).

Reintroductions are essential to maintain wild populations. Improving the survival rate of reintroduced gharials is a priority. The following measures are proposed (Maskey, 1989; Cadi *et al.*, 2005):

1. Releasing gharials at sites with undisturbed habitat and where monsoon floods are moderate (e.g. Rapti River).
2. Releasing gharials during the best period for settlement before the monsoon (February).
3. Releasing individuals in other protected areas such as the Bardia National Park (Babai and Karnali rivers) which offer good quality habitats with low disturbance (Smith *et al.*, 1996; Ballouard *et al.*, 2007).
4. Releasing young gharials (2 to 5 years old).
5. Long-term monitoring of released animals.

Conservation success will depend on the acceptance and participation of local people. Implementation of conservation initiatives must be achieved on a long-term basis through awareness, education and the involvement of local people with an interest in the area. Buffer zone communities must be a key component as it involves people in resource management of the park throughout a participatory approach (Bajimaya, 2006). For example, fishermen could be employed as 'gharial sentinels'. The implementation of strict rules should be compensated by practical solutions, for example construction of fishing ponds. International cooperation is required, notably to help with the acquisition of biological knowledge,

funding and education campaigns (GCA, 2008). Cooperation between Nepal and India could allow a common legal protection for gharials passing through the dam situated near the frontier. The implementation of conservation measures is important because in the absence of any action the recent trend suggests this species will become extinct. As a 'surrogate species' combining the concepts of sentinel, umbrella and flagship species, conservation of the gharial and preservation of its habitat could be a vehicle for maintaining biodiversity of the whole freshwater ecosystem.

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